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DEFLECTION YOKES

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Celco

Constantine Engineering Laboratories Company

70 CONSTANTINE DRIVE
MAHWAH, N. J. 07430
PHONE: 201 - 327-1123

Nov. 6, 1968

Mr. T. Nelson
Systems Consultant
Box 32
Schooleys Mountain, N. J. 07870

Dear Mr. Nelson

CELCO Writing Yokes are used in an increasing number of computer and alpha-numeric sequential and random positioning types of cathode ray tube displays. The enclosed data sheets summarize a wide range of precision, air core, Hi-Q, and air core with ferrite shield writing yokes.

Physical characteristics include flange or cylindrical mounting. Length is 1 7/16" with 11/16" and 1" units also available.

Particularly interesting is the series of curves showing frequency versus relative flux, reactance, inductance, effective resistance and Q.

Application notes on writing yokes and a reprint entitled "A New Resolution Chart for Imaging Systems" by Igor Limansky of Westinghouse are included. The reprint describes a method for calculating sine wave spatial frequency responses from the square wave modulation transfer function. This may be measured by the CELCO Spot Analyzer.

Development continues in our laboratories on yokes, amplifiers, correction circuits and special high speed focus coils for use in your present and future display systems.

Very truly yours,

John M Constantine

John M. Constantine
President and Yoke Designer

A new resolution chart for imaging systems

This pattern gives results superior to others now used. And its companion worksheet simplifies the process to boot.

By Igor Limansky,
Aerospace Div., Westinghouse Defense and Space Center, Baltimore, Md. 21203.

A basic precept of an imaging system is that electrical and spatial frequencies are equivalent when a scanning process is used. When an image is scanned, any variations in its light flux are noted as different frequencies —the smaller the detail size (i.e., the faster the change of flux), the higher the apparent frequency. The scanning aperture's effect on definition is determined as an *aperture response* or frequency response characteristic.

In both the electrical and optical disciplines, the *square wave modulation* transfer function depends upon system bandwidth. Optical workers, though, prefer the *sine wave modulation* transfer function which more accurately represents the *spatial bandwidth.* They do use the square wave function, however, because it is relatively easy to generate a test pattern of bars. You must convert the square wave test results to sine wave information in order to accurately represent the frequency response of the unit under test, or to combine the responses of several units in cascade to get their total response. An example[2] of such a system of cascaded components is a fluoroscopic instrument using television techniques. To determine the total resolving power of the instrument, the spatial frequency response of each component is measured by square wave tests. These results are converted to sine wave response factors, and plotted against *line pairs/mm* (the spatial frequency). The three plotted curves (focal spot resolution, fluorescent screen resolution, and the TV camera chain resolution) are combined to give the overall resolution of the entire instrument system.

New resolution chart

The new chart presented here is a maximum-contrast, diminishing-bar test pattern. The computation of the sine wave modulation transfer function uses each of the component bar groups. We also include a new worksheet which greatly simplifies the computation. The square wave response is converted to a sine wave response according to Coltman's method.[2]

The conversion equation

The square wave to sine wave conversion depends upon a function[3] which transforms a series of points in the square wave response plane to the sine wave response plane. We resolve a square wave input into its Fourier components, multiplying each component by the sine wave response of the system R(N), which corresponds to the frequency N, of the component. This gives the square wave output response r(N), expressed as a series in R(kN). Solving for R(N), we get (from Coltman),

$$R(N) = \frac{\pi}{4}\left[r(N) + \frac{r(3N)}{3} - \frac{r(5N)}{5} + \frac{r(7N)}{7} + \cdots + B_k\frac{r(kN)}{k} + \cdots\right] \quad (1)$$

$R(N)$ is the output sine wave response

$r(N)$ is the output square wave response

$B_k = (-1)^m(-1)^{\frac{k-1}{2}}$, for $r = m$

$B_k = 0$, for $r < m$

$k = 1, 3, 5, \cdots$ (odd values only)

$m =$ the total number of prime factors of k

$r =$ the number of *different* prime factors of k

$N =$ the frequency of the test pattern

Note that only *odd* terms are present in equation (1). Presently used resolution patterns have *odd and even* multiples of some basic line number N. For example, Westinghouse chart ET-1332A[4] has ten test pattern frequencies—N, 2N, 3N, 4N, . . . 9N, 10N—of which only the odd frequencies are useful in computing R(N) by equation (1).

Reprinted from The Electronic Engineer • June 1968

Frequency response, imaging systems, aperture response, and test charts

We are all familiar with the concept of frequency response. If a system has a "flat" frequency characteristic, then the output signal amplitude doesn't vary until, at some high frequency, it begins to drop off. When it drops below the flat portion to some defined level (generally —3 dB), the frequency of this point is noted and called the cut-off frequency of the system. The cut-off frequency is a measure of the speed of response of the system—it tells us whether or not the circuitry can follow the changes of the input signal as the changes become faster and faster. (Pulse testing does exactly this. The relationships between the rise time of a pulse and the cut-off frequency of the amplifier passing it are well-known.)

We have been speaking of systems with electrical input and output signals, but the frequency response concept holds true for any kind of system. And we can always draw an analogy between the "frequency" response of a non-electrical system and that of an electronic system. Often, however, there is a two-fold problem: how to define the frequency limit, and how to measure it—how to put a number on it, if you will, that is meaningful and useful to others.

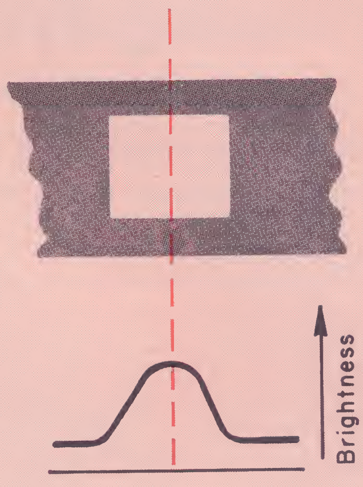
Imaging systems

The importance of the resolution of a lens should be apparent when we think of television. In an imaging system, the *resolving power* of a lens is often the limiting response characteristic because it determines the smallest image detail we can see.

When the imaging system is linear (that is, the output is proportional to the input), it may be characterized by a single variable. One such variable is the *spatial frequency response*—the response to some test pattern that tells us the finest detail we'll be able to see. The bar chart is the generally agreed upon method to determine the resolving power of a lens. It is the tool usually used in spatial frequency response measurements.

Aperture response

Schade's[1] work has popularized the term *aperture response*. Think of scanning the bar chart just mentioned. Each element of the scan may be considered an aperture. You can compute the characteristics of the response if the size and flux distribution of the aperture are known. The system limits are shown by, for example, the scan of a thin white bar on a black background. The scanned output will look as though the bar changed gradually, rather than sharply, from black to white. It is analogous to the response to a fast pulse of a system with a bandwidth too narrow for the pulse. The system degrades the rise and fall times of the input pulse, which emerges looking more triangular than rectangular. The aperture response of a scanning system is very significant. For example, you can calculate the bandwidth required for a television channel if you know the number of lines needed for a given resolution and the time per frame.



Test charts

A resolution chart is made of light and dark bars with sharp transitions between them. They are grouped in sets of decreasing width and spacing. Scanning the chart gives rise to a series of pulses, and so such a method is known as *square wave* testing. Aperture response characteristics are properly associated only with square wave tests.

Aperture response curves are not too meaningful for patterns other than square waves, and can't be easily combined to get the overall spatial frequency response of a chain of imaging systems. For this purpose, a *sine wave* pattern is much more useful, because the overall response is simply the product of the individual responses, as in any electrical system.

Sine wave responses are easy to handle, but the test patterns are difficult to generate. On the other hand, square wave test patterns are easy to generate but the responses are difficult to handle. However, a square wave input (in a linear system) can be broken down into its Fourier sine wave components which, in turn, are operated upon by the sine wave response of each system in the chain. The outputs are then combined to give the total system response. Much work has been done in attempts to simplify the conversion of square wave measurements into sine wave responses. This article describes a new chart and an orderly method for obtaining such results.

Resolution chart (continued)

Making the chart

To make the new test pattern we prepare a chart with 10 or 11 frequencies that are odd multiples of some basic line number, N. The test pattern frequencies are N, 3N, 5N, . . . 21N, for an 11-group chart. Figure 1 shows the original and the new resolution charts, and Fig. 2 shows a monoscope target using the new pattern.

The computation worksheet

Equation (1) tells us that to compute one point on the sine wave response curve we must know all the data points on the square wave response curve with lower spatial frequencies. To get the other points on the sine wave curve, we must substitute kN for N in equation (1). The resulting set of equations defines the sine wave response curve according to the experimental values found from the square wave response. It is shown in the form of a computation worksheet in Fig. 3. The worksheet lets us compute the sine wave response data directly from the experimental values we obtained from the resolution chart of Fig. 1b. Note that this worksheet eliminates the need to draw an estimated square wave response curve and to pick off appropriate values from it.

The new computation worksheet does these things for us:

- it defines the mathematical operations we must perform on each measured value
- it groups the data into positive and negative factors for each test pattern frequency
- it indicates the subsequent mathematical operations needed to produce the sine wave response curve points.

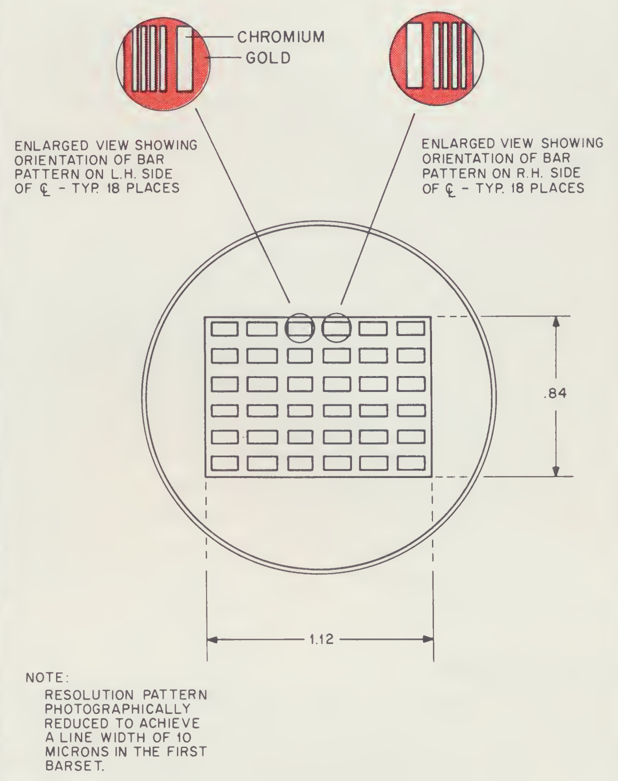


Fig. 2. This monoscope target uses the new resolution chart. Built into a TV camera tube and scanned, it generates test and alignment signals.

Using the chart and worksheet

Let's use the new chart and worksheet to find the aperture response of a TV camera lens. The method we'll follow was described by Reininger et al,[5] and requires the equipment shown in Fig. 4. The complete measurement routine includes:

- a visual estimate of the limiting resolution (as a check on the final results)
- choice of object distance so that the limiting resolution falls at a high number group (d = 404.5 cm for this lens)
- computation of reduction factor R, (focal length

Fig. 1. Wide black and white bars represent 100% modulation (the extremes of illumination). Decreasing bar widths and spacings are groups of increasing line number.

SQUARE WAVE RESPONSE VALUES	COMPUTATION OF R (N)		COMPUTATION OF R (3N)		COMPUTATION OF R(5N)	COMPUTATION OF R (7N)
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE		
$r(N) = 0.970$	$r(N) = 0.97$					
$r(3N) = 0.870$	$\frac{r(3N)}{3} = 0.29$		$r(3N) = 0.870$			
$r(5N) = 0.720$		$\frac{r(5N)}{5} = 0.144$			$r(5N) = 0.72$	
$r(7N) = 0.610$	$\frac{r(7N)}{7} = 0.087$					$r(7N) = 0.61$
$r(9N) = 0.520$			$\frac{r(9N)}{3} = 0.173$			
$r(11N) = 0.430$	$\frac{r(11N)}{11} = 0.039$					
$r(13N) = 0.330$		$\frac{r(13N)}{13} = 0.025$				
$r(15N) = 0.260$		$\frac{r(15N)}{15} = 0.017$		$\frac{r(15N)}{5} = 0.052$	$\frac{r(15N)}{3} = 0.086$	
$r(17N) = 0.210$		$\frac{r(17N)}{17} = 0.012$				
$r(19N) = 0.160$	$\frac{r(19N)}{19} = 0.0084$					
$r(21N) = 0.100$	$\frac{r(21N)}{21} = 0.0048$		$\frac{r(21N)}{7} = 0.014$			$\frac{r(21N)}{3} = 0.033$
	$\Sigma_1(+) = 1.399$	$\Sigma_1(-) = 0.199$	$\Sigma_3(+) = 1.057$	$\Sigma_3(-) = 0.052$	$\Sigma_5(+) = 0.806$	$\Sigma_7(+) = 0.643$
	$\frac{4}{\pi} R(N) = \Sigma_1(+) - \Sigma_1(-) = 1.200$ $R(N) = 0.941$		$\frac{4}{\pi} R(3N) = \Sigma_3(+) - \Sigma_3(-) = 1.005$ $R(3N) = 0.786$		$\frac{4}{\pi} R(5N) = \Sigma_5(+)$ $R(5N) = 0.633$	$\frac{4}{\pi} R(7N) = \Sigma_7(+)$ $R(7N) = 0.505$

$R(9N) = \frac{\pi}{4} r(9N) = 0.408$

$R(11N) = \frac{\pi}{4} r(11N) = 0.338$

$R(13N) = \frac{\pi}{4} r(13N) = 0.259$

$R(15N) = \frac{\pi}{4} r(15N) = 0.204$

$R(17N) = \frac{\pi}{4} r(17N) = 0.165$

$R(19N) = \frac{\pi}{4} r(19N) = 0.125$

$R(21N) = \frac{\pi}{4} r(21N) = 0.079$

Fig. 3. The new worksheet brings order and simplicity to the computation of the sine wave response. Measured square wave data is entered into the column at the extreme left; all subsequent operations are clearly indicated in their appropriate positions.

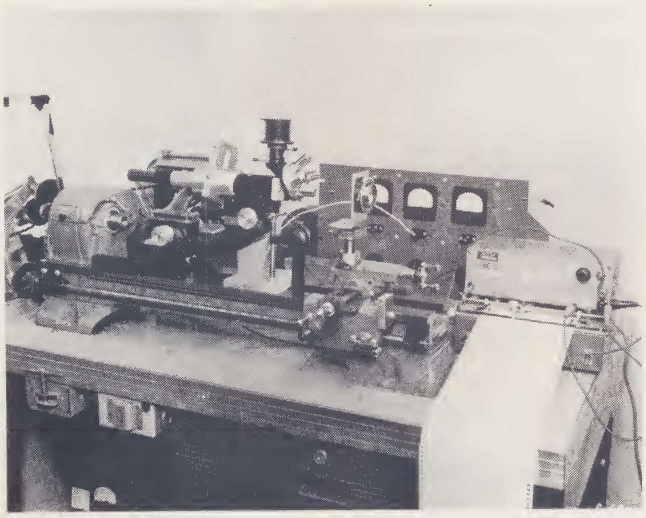
f = 6.3 cm for this lens; $R = \frac{d-f}{f} = 63$)

- calculation of the line numbers of the groups of bars in the image plane
- square wave test (aperture response).

The square wave response of the lens and the filled-in worksheet are shown in Figs. 5 and 3, respectively.

To fill out the worksheet, first enter the peak-to-peak amplitudes of each of the 11 pulse groups into the left-hand column. You can read these amplitudes directly

(Continued on following page)



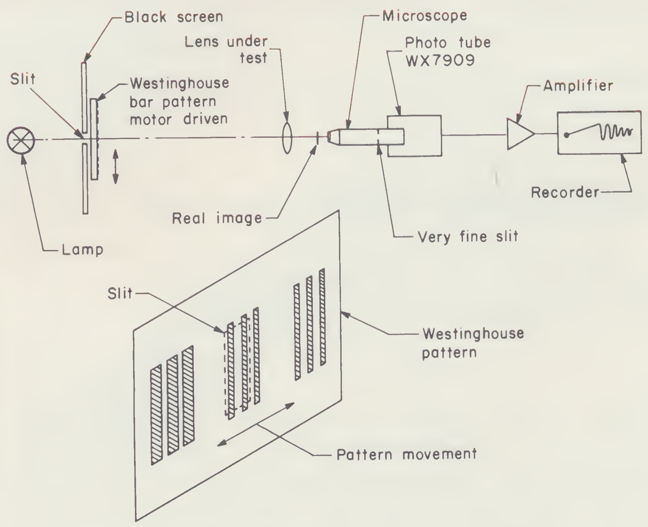


Fig. 4. Measuring the square wave response (aperture response) of a lens. Diagram shows equipment operation.

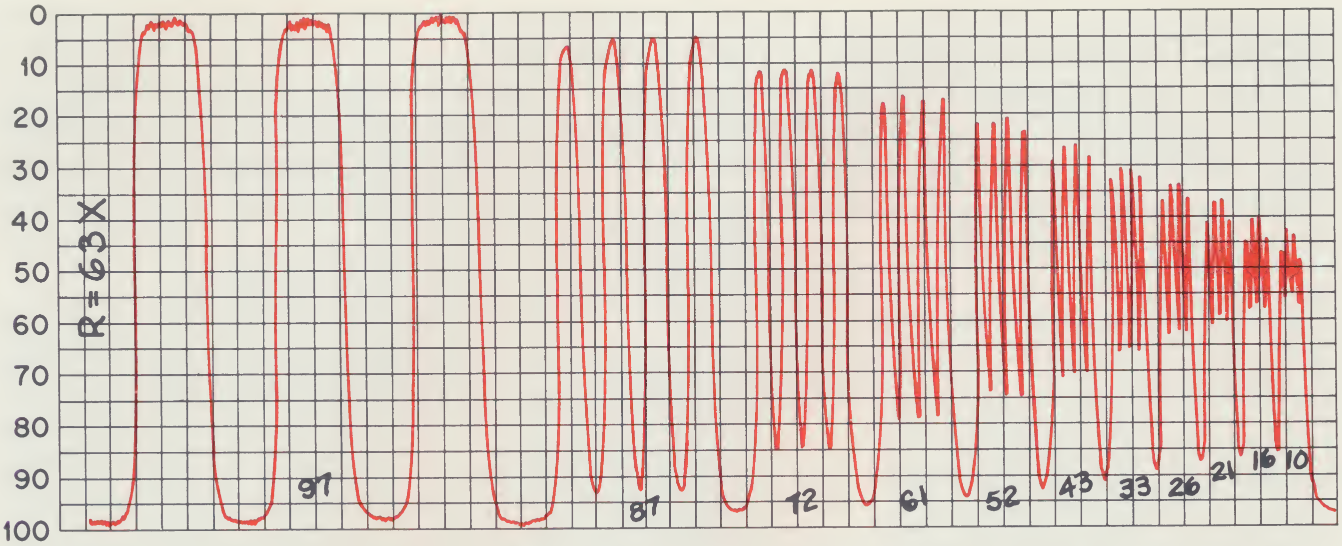


Fig. 5. This is the square wave response of the lens, measured with the equipment of Fig. 4. Note the 11 groups of pulses (the r(kN)) and their odd-harmonic relationship. The peak-to-peak amplitude of each group is indicated.

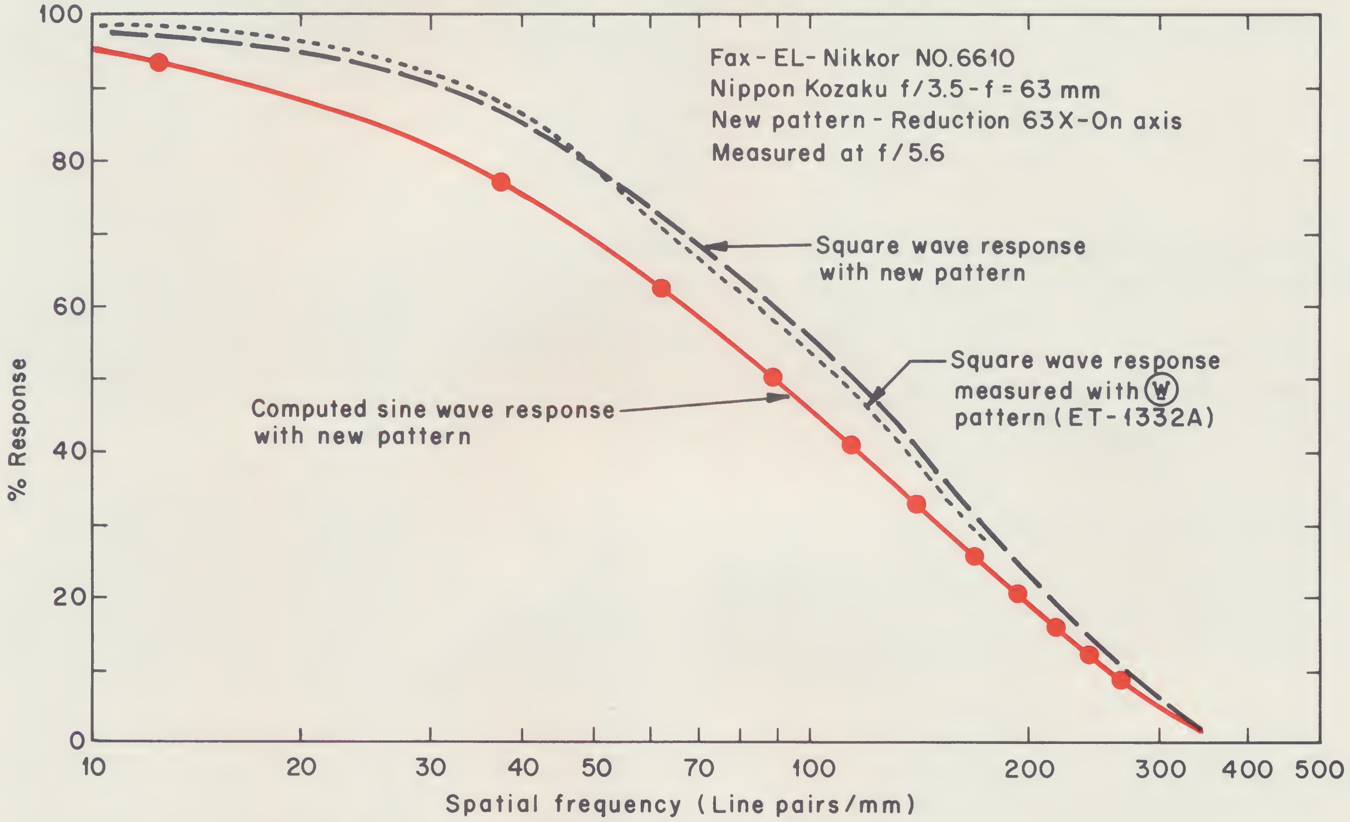


Fig. 6. Here's the result of the new pattern—the sine wave frequency response of the lens. Square wave responses are shown for comparison.

Resolution chart (continued)

from the strip chart against its 0 - 1 scale (0.97, 0.87, and so forth). Then, fill in the rest of the blocks according to the operation indicated in each of them (i.e.,

$$\frac{r(3N)}{3} = \frac{0.87}{3} = 0.29).$$

Next, add the positive and negative columns and place the totals at the column bottoms. Now subtract the negative total from the positive total in each pair of columns for all R (kN), and multiply the results by $\frac{\pi}{4}$.

These numbers are the sine wave responses for the frequencies R(N), R(3N), R(5N), and so forth.

R(9N) through R(21N) do not need additions or subtractions; they are computed as shown at the bottom of the worksheet.

We compute the frequencies of the bar groups by multiplying the line pairs/mm (l.p./mm) by the reduction factor (63 for our example). In the bar chart we used for these measurements, the line pairs were spaced 0.2, 0.6, 1.0, 1.4, . . . 3.8, and 4.2 l.p./mm (corresponding to the 11 odd harmonics of 0.2 l.p./mm from 1 through 21). Therefore, we plot the square wave responses r(kN), and the sine wave responses R(kN), at 12.6 l.p./mm (63 x 0.2), 37.8 l.p./mm

(63 x 0.6), and so forth. The curves are shown in Fig. 6.

Sources of error

The mathematics of conversion between a curve in the square wave response plane and a point in the sine wave response plane is exact. But the bar chart and the mathematical transformation deal with a one- or two-dimensional system, whereas imaging is a three-dimensional process. We may, therefore, question using maximum-contrast bar patterns interchangeably with true sine wave test patterns. For example, sine wave response curves determined from positive and negative reproductions of the new resolution chart should, in theory, be identical. They are not, and the difference between them increases with spatial frequency. Several factors can cause errors in the measured responses. If a lens shows lens flare, for instance, the light level of the surroundings will influence the results. A high-contrast, high-line-number bar pattern can act as a Ronchi grating and produce spurious effects. It is also possible that the results from reflective and transmissive patterns can differ if the light is partially coherent.

Superior features

The new resolution chart has definite advantages. Because it is a bar chart, it is relatively easy to ensure accuracy and reproducibility in its manufacture. One feature of the new chart is that it provides more range than some now used. Another is that with the new computation worksheet, we greatly reduce the numerical effort needed to get the sine wave response values. Further evaluation will determine whether or not the new bar chart gives the values with sufficient accuracy to use interchangeably with true sine wave test pattern results.

Acknowledgement

W. G. Reininger made the measurements for this article following methods and techniques developed by him and G. W. Fath.

Bibliography

1. O. H. Schade, "Electro-optical characteristics of television systems, Part II," *RCA Review*, Vol. 9, No. 2, June 1948.
2. J. W. Coltman, "The specification of imaging properties by response to sine wave input," *Journal of the Optical Society of America*, Vol. 44, No. 6, June 1954.
3. W. Altar, Westinghouse Research Memorandum, No. 60-94410-14-19.
4. R. J. Doyle, "Simplified resolution measurement," *Electronic Industries*, Vol. 21, March, 1962.
5. W. G. Reininger, A. S. Jensen, and W. G. Beran, "Research in advanced photoelectric information storage," ASTIA No. AD-423-982; Technical Documentary Report No. RTD-TDR-63-4134. Nov. 1963. Contract No. AF(657) 8715, for Air Force Avionics Lab. Research and Technology Div., Air Force Systems Command: WPAFB, Ohio.

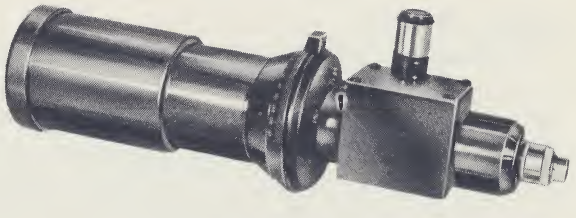
Uncited references

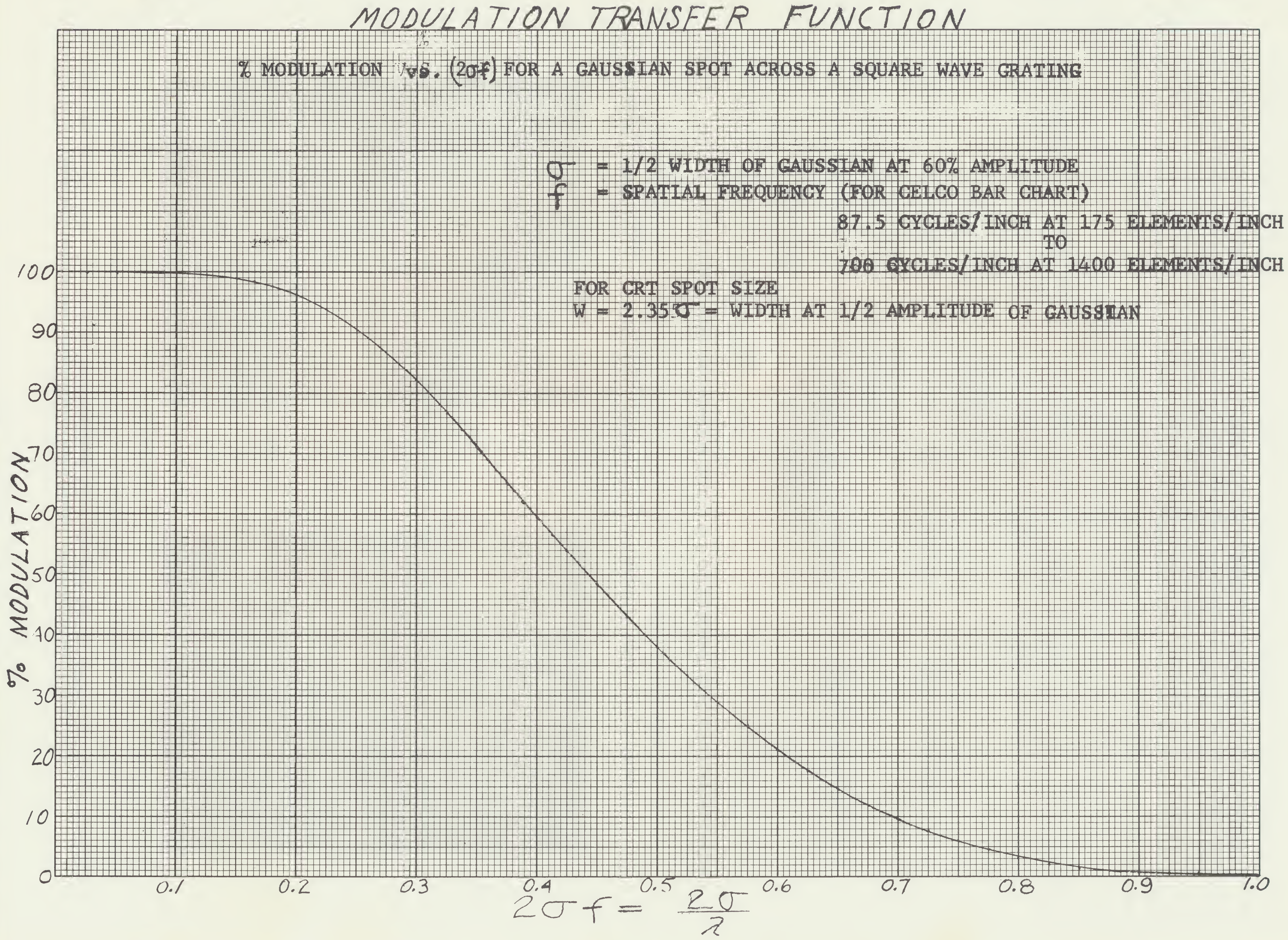
I. C. Gardner and F. E. Washer, "Method for determining the resolving power of photographic lenses," National Bureau of Standards Circular No. 533, 20 May 1953.

J. K. Robe, "Storage tube resolution," University of Illinois, Report No. R-93, March 1957; ASTIA No. AD-129131, Contract No. DA-36-0390SC-56695.

O. H. Schade, "Optical image evaluation," National Bureau of Standards Circular 525, 29 April 1954.

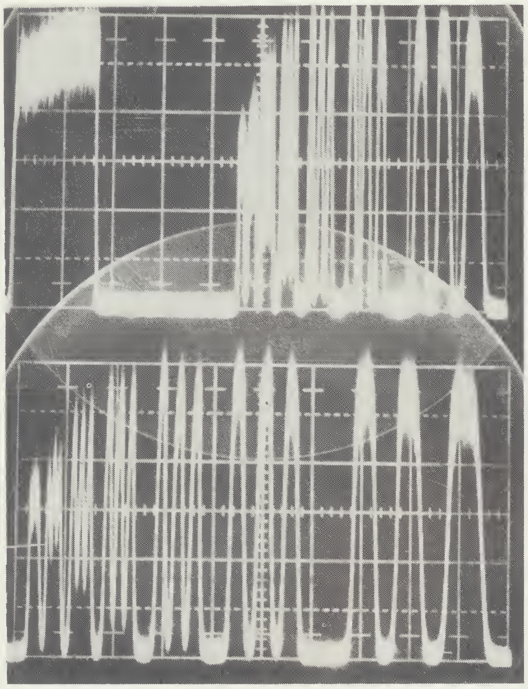
INFORMATION RETRIEVAL:
Instruments and measurements, Electro-optics




MODULATION TRANSFER FUNCTION
% MODULATION vs. (2σf) FOR A GAUSSIAN SPOT ACROSS A SQUARE WAVE GRATING
σ = 1/2 WIDTH OF GAUSSIAN AT 60% AMPLITUDE
f = SPATIAL FREQUENCY (FOR CELCO BAR CHART)
87.5 CYCLES/INCH AT 175 ELEMENTS/INCH
TO
700 CYCLES/INCH AT 1400 ELEMENTS/INCH
FOR CRT SPOT SIZE
W = 2.35σ = WIDTH AT 1/2 AMPLITUDE OF GAUSSIAN
% MODULATION
100
90
80
70
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
2σf = 2σ/λ

SQUARE WAVE MODULATION COEFICIENT FOR SQUARE WAVE MTF.
Oscillograms of CRT spot scanned across bar chart using a CELCO Spot Analyzer.

5 mv/cm

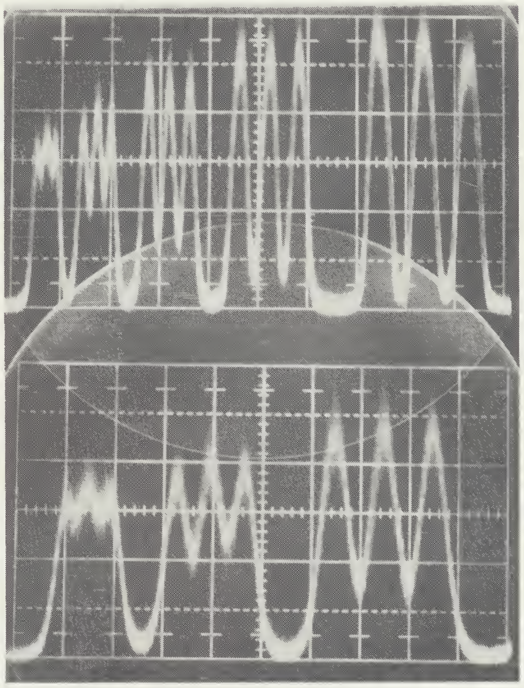


A

B

5 mv/cm

5 mv/cm



C

D

5 mv/cm

1400 700 1000 500 350 250 175

Elements Per Inch

1400 1000 700

Elements Per Inch

A. 7 gratings, one reference slit to determine the 100% modulation point.
Horiz. Scale .5 msec/cm uncal.

B. 7 grating expanded time scale.
Horiz. Scale .2 msec/cm uncal.

Spatial frequency range $\frac{175}{2}$ cycles/in. to $\frac{1400}{2}$ cycles/in.

C. Last 5 gratings responses
Horiz. Scale .1 msec/cm uncal.

Spatial frequency range $\frac{350}{2}$ cycles/in. to $\frac{1400}{2}$ cycles/in.

D. Last 3 grating responses
Horiz. Scale 50 μs/cm uncal.

Spatial frequency range $\frac{700}{2}$ cycles/in. to $\frac{1400}{2}$ cycles/in.

% MODULATION	# ELEMENTS/IN.	SPATIAL FREQ.	$2\sigma f$	σ (Std.Dev.)	W= 2.35σ
100	175	87.5	-	-	-
100	250	125	-	-	-
100	350	175	-	-	-
89	500	250	.27	.00054	.00126"
66	700	350	.35	.00050	.00117"
37	1000	500	.51	.00051	.00122"
10	1400	700	.70	.00050	.00117"

WRITE, DIDDLE, TICKLER — YOKES OR WINDINGS

"RITE-THRU" YOKES

CRT displays often require small, incremental, high-velocity displacement of the CRT spot along with large amplitude, slower deflections. Many systems employ one deflection system for the slower scan and a second system for high-speed writing. The high-speed magnetic deflection coils used for this latter purpose are variously termed write, diddle, tickler yokes or windings. "Rite-Thru" yokes use common windings for write, positioning and vector generation functions.

Another approach to the problem is the use of electrostatic plates built into the CRT. This is costly, resolution is generally poor, and it introduces problems of distortion, character shrinkage, expansion or both, as well as high voltage deflection and shielding difficulties.

Magnetic deflection and character generation permits higher resolution using standard low cost CRTs. High current transistor drivers are pushing the state of the art to the point where 5-20 MHz bandwidth, 1-5 ampere amplifiers driving 1-10 μH yokes are realizable.

The selection of a yoke depends on the Display System requirements such as cost, spot velocity, resolution, size of vectors and/or alpha-numerics, Cathode Ray Tube, accuracy, residual, settling, deflection amplifiers, permissible coupling between yokes and focus coil, CRT gun coupling and cross coupling in the yoke-amplifier system.

Separate Write Yokes and position Yokes, of course, increase Write Yoke — CRT gun coupling due to the proximity of write yoke field and gun structure. (See Fig. 1.)

CELCO Writing Yokes are characterized by core material, length, inductance, and current required for 2° deflection at 10 KV. Curves showing flux response, effective resistance, inductance, Q, and inductive reactance accompany each set of coil data in the writing yoke section of the Display Engineering Manual.

AW, GW and KW writing yokes are made with Celcoloy #22 and are used for precision displays where low residual and symmetry are required with maximum sensitivity for a given length. Relative flux response vs. frequency indicates useful performance up to 1 MHz with a 3 db penalty in driving current.

BW, HW and LW air core yokes inherently have no residual, use more power, and are subject to proximity effects of the environment, such as shields, mounting devices, CRT gun, chassis, yokes, focus coils, centering coils and any other metallic objects in the vicinity of the air core yoke assembly.

NW air core yokes with ferrite shields reduce proximity effects and the power required for deflection as compared to plain air core yokes. Quantity production costs are lower with this type structure than with regular cored yokes.

CW, JW and MW yokes made with Celcoloy #18 are for high sensitivity, high Q, highest frequency applications where absolute residual and precision parameters are not important.

The "W" Write Yokes are usually mounted behind the main deflection yoke. Write Yoke — CRT gun coupling at high frequencies causes cross coupling and defocussing effects. Many applications with small, incremental deflection are possible since the effects may be negligible. The centers of deflection for the main yoke and the Write Yokes are displaced and large deflections with the Write Yoke may produce unacceptable non-linearities and loss of resolution at the CRT face.

When large vectors must be produced, the use of rear mounted Writing Yokes is not recommended. "Rite-Thru" yoke structures must be used for positioning, vector and alpha-numeric generation.

At low frequencies the yoke-amplifier bandwidth and linearity design problems have been solved by using a choice of appropriate standard catalogue AY, BY, CY, DY, FY, GY, GD, HD, QD, QY, FD, HDN, or DN deflection yokes or Deflectrons in conjunction with appropriate CELCO deflection amplifiers, DA-PP025 through DA-PP6; DA-PP2N-1 through DA-PP8N-1; DA-PP2N-3 through DA-PP8N-3; DA-PP2N-4 through DA-PP8N-4; DA-PP2N-5 through DA-PP8N-5; and DA-PP2N-6 through DA-PP8N-6 covering a range of from .5 amps to 16 amps, with small signal bandwidth from 250 Hz to 2 MHz.

When standard yoke-amplifiers are not available to meet a set of display requirements, the driver-yoke system must be developed, probably using state of the art transistor devices, yoke material and design techniques.

Small signal, high frequency, high current deflection ampli-

Celco YOKES

Constantine Engineering Laboratories Company

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WRITE, DIDDLE, TICKLER — YOKES OR WINDINGS

"RITE-THRU" YOKES

fiers are easier to design than high current, high frequency, wide band amplifiers; consequently, designers have used a single yoke with a high inductance winding for large signal deflection with an auxiliary Write winding embedded in the same yoke form. The advantage is best sensitivity (lowest LI^2) for a given set of deflection requirements. The difficulties that arise due to the close coupling between main and Write Yokes have been circumvented, to a degree, using special CELCO low coupling yokes of the LY- high Q, high sensitivity type. A direct or resonant drive may be used for the main winding and a resonant circuit for "diddling".

Most high resolution, high performance display systems use a single yoke and amplifier for position, write and vector generation. Many ingenious drivers have been developed to minimize the power which must be dissipated by the power transistors or vacuum tubes. In the "Voltage on Demand System", a large voltage is applied to the deflection yoke windings only during the transition time or period of high rate of change of current. When the transient requirement has passed, the voltage is reduced or clamped to a low value to produce the required positioning current.

Incremental drivers supply the positioning and alphanumeric currents in small, fast increments into low inductance yokes, and switch currents sequentially on computer commands to produce the desired display. High inductance, high voltage incremental switching has also been used.

Splitting of single-ended yoke windings to further reduce effective yoke inductance, using multiple drivers with parallel inputs, can reduce positioning times by a factor of 2 in existing state of the art, brute force, wide band amplifiers. This is possible due to low coupling coefficient between the halves of single-ended yoke windings.

High resolution, low inductance yokes are an anomaly. Very often some type of dynamic astigmatism correction is required to realize the requirements of spot growth on the face of the CRT due to coma and astigmatism caused by deflecting fields that are not appropriate for the electron optics. Low inductance is a result of few turns approximately distributed per Fourier, sine, cosine or some power of the transcendental functions. When turns are too few, there are large errors in magnetic field directions and magnitudes as required by the field equations.

The final display system is the result of a series of compromises between ideal solutions and practical, realizable components by combining the experience and ingenuity of CRT, Deflection Component and Display Designers to achieve the required performance at an acceptable price in the lead time available.

John M Constantine

Yoke Designer & President

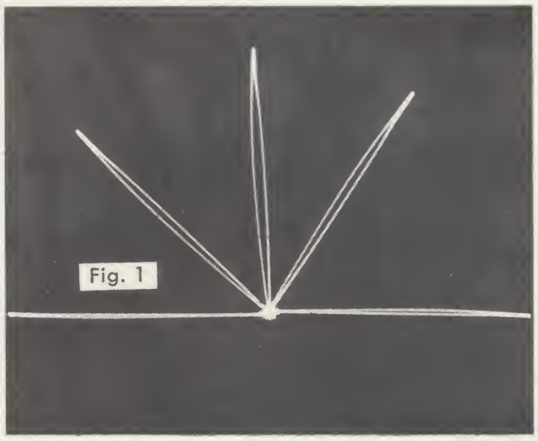
CROSS — COUPLING DUE TO GUN STRUCTURE

TEST CONDITIONS

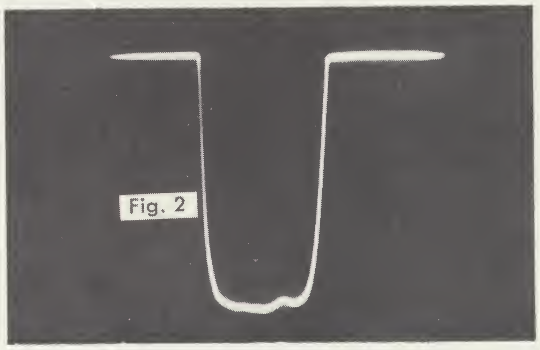
A. CRT 10 UP at 10 kV

B. YOKE Y axis energized with 6.2 A, 4 μsec current pulse with approximately 2 μsec rise time. X axis winding open (no difference if short circuited).

C. Yoke was rotated in approximately 45° steps (clockwise) as viewed from the front of the CRT.



Pattern obtained for successive 45° rotations of yoke with respect to the CRT. Deflection was approximately 7.5 cm on CRT face, cross coupling loop open about 0.35 cm.



Waveform used for deflection. About 1.1 μsec/cm on CRT face.

WRITE, DIDDLE, TICKLER — YOKES OR WINDINGS

"RITE-THRU" YOKES

CRT displays often require small, incremental, high-velocity displacement of the CRT spot along with large amplitude, slower deflections. Many systems employ one deflection system for the slower scan and a second system for high-speed writing. The high-speed magnetic deflection coils used for this latter purpose are variously termed write, diddle, tickler yokes or windings. "Rite-Thru" yokes use common windings for write, positioning and vector generation functions.

Another approach to the problem is the use of electrostatic plates built into the CRT. This is costly, resolution is generally poor, and it introduces problems of distortion, character shrinkage, expansion or both, as well as high voltage deflection and shielding difficulties.

Magnetic deflection and character generation permits higher resolution using standard low cost CRTs. High current transistor drivers are pushing the state of the art to the point where 5-20 MHz bandwidth, 1-5 ampere amplifiers driving 1-10 μH yokes are realizable.

The selection of a yoke depends on the Display System requirements such as cost, spot velocity, resolution, size of vectors and/or alpha-numerics, Cathode Ray Tube, accuracy, residual, settling, deflection amplifiers, permissible coupling between yokes and focus coil, CRT gun coupling and cross coupling in the yoke-amplifier system.

Separate Write Yokes and position Yokes, of course, increase Write Yoke — CRT gun coupling due to the proximity of write yoke field and gun structure. (See Fig. 1.)

CELCO Writing Yokes are characterized by core material, length, inductance, and current required for 2° deflection at 10 KV. Curves showing flux response, effective resistance, inductance, Q, and inductive reactance accompany each set of coil data in the writing yoke section of the Display Engineering Manual.

AW, GW and KW writing yokes are made with Celcoloy #22 and are used for precision displays where low residual and symmetry are required with maximum sensitivity for a given length. Relative flux response vs. frequency indicates useful performance up to 1 MHz with a 3 db penalty in driving current.

BW, HW and LW air core yokes inherently have no residual, use more power, and are subject to proximity effects of the environment, such as shields, mounting devices, CRT gun, chassis, yokes, focus coils, centering coils and any other metallic objects in the vicinity of the air core yoke assembly.

NW air core yokes with ferrite shields reduce proximity effects and the power required for deflection as compared to plain air core yokes. Quantity production costs are lower with this type structure than with regular cored yokes.

CW, JW and MW yokes made with Celcoloy #18 are for high sensitivity, high Q, highest frequency applications where absolute residual and precision parameters are not important.

The "W" Write Yokes are usually mounted behind the main deflection yoke. Write Yoke — CRT gun coupling at high frequencies causes cross coupling and defocussing effects. Many applications with small, incremental deflection are possible since the effects may be negligible. The centers of deflection for the main yoke and the Write Yokes are displaced and large deflections with the Write Yoke may produce unacceptable nonlinearities and loss of resolution at the CRT face.

When large vectors must be produced, the use of rear mounted Writing Yokes is not recommended. "Rite-Thru" yoke structures must be used for positioning, vector and alphanumeric generation.

At low frequencies the yoke-amplifier bandwidth and linearity design problems have been solved by using a choice of appropriate standard catalogue AY, BY, CY, DY, FY, GY, GD, HD, QD, QY, FD, HDN, or DN deflection yokes or Deflectrons in conjunction with appropriate CELCO deflection amplifiers, DA-PP025 through DA-PP6; DA-PP2N-1 through DA-PP8N-1; DA-PP2N-3 through DA-PP8N-3; DA-PP2N-4 through DA-PP8N-4; DA-PP2N-5 through DA-PP8N-5; and DA-PP2N-6 through DA-PP8N-6 covering a range of from .5 amps to 16 amps, with small signal bandwidth from 250 Hz to 2 MHz.

When standard yoke-amplifiers are not available to meet a set of display requirements, the driver-yoke system must be developed, probably using state of the art transistor devices, yoke material and design techniques.

Small signal, high frequency, high current deflection ampli-

PRECISION Celco COMPONENTS

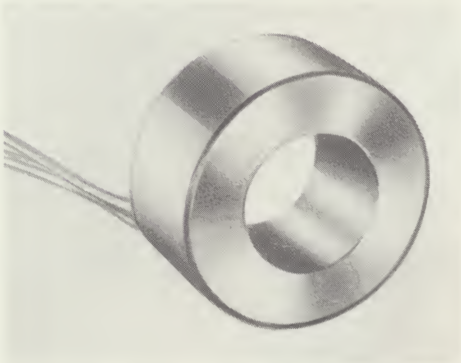
HIGH SENSITIVITY

AW314- Precision Core
BW314- Air Core
CW314- Hi-Frequency Core
NW315- Air Core, Ferrite Shield

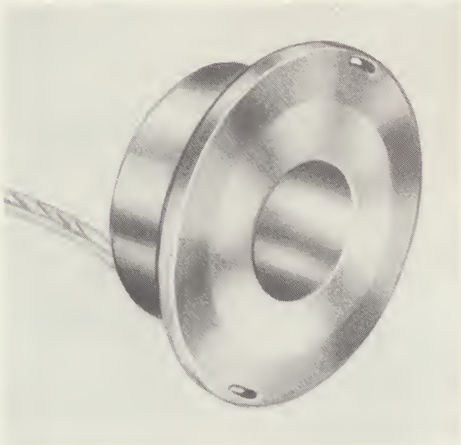
MAGNETIC WRITING YOKES

for HIGH FREQUENCY TICKLER APPLICATIONS

for 1 7/16" NECK CRTs

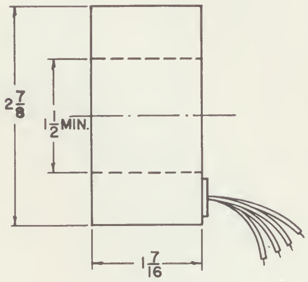


AW314-	Precision Core, up to 1 MHz
BW314-	Air Core, up to 20 MHz
CW314-	Hi-Q, Hi-Frequency to 30 MHz
NW315-	Air Core, Ferrite Shield to 26 MHz

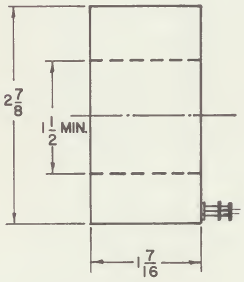


AWA314-
BWA314-
CWA314-
NWA315-
Flanged Units for "Piggy-Back" Attachment to Modified CELCO Standard Yokes

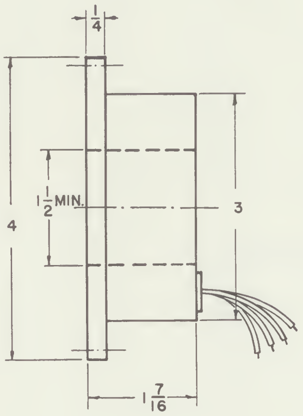
- Wide Range of Celcoloy Magnetic Materials for Optimizing Performance
- Precision Core for Vectors
- Magnetic Writing with Standard Low Cost CRTs Eliminates Electrostatic Deflection Plates
- Character Distortion Due to Interaction of Electrostatic Fields is Minimized
- Stroke, or Resonant Type Character Formation
- Minimum Coupling Between Position and Write Yokes
- Resonant Frequencies to 30 MHz
- Minimum LI^2
- Wide Range of Inductances from 1 μH Up
- Push-Pull or Single-Ended



AW314-
BW314-
CW314-



NW315-



AWA314-
BWA314-
CWA314-
NWA315-

Celco YOKES

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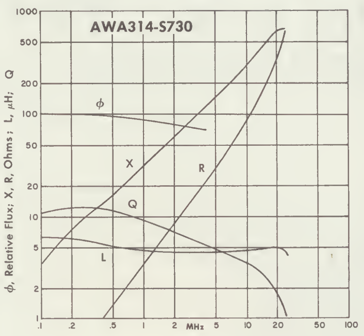
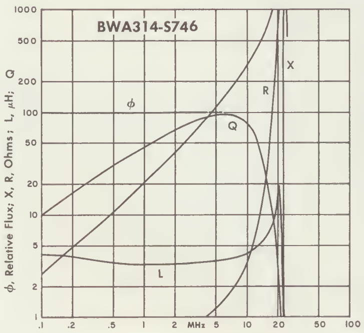
LOW LI² WRITING YOKES

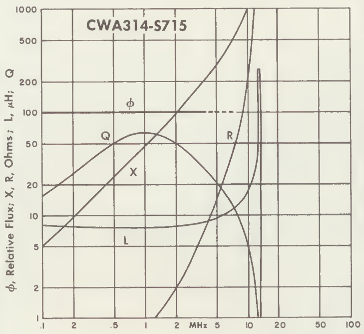
PERFORMANCE DATA for 2° DEFLECTION at 10 kV

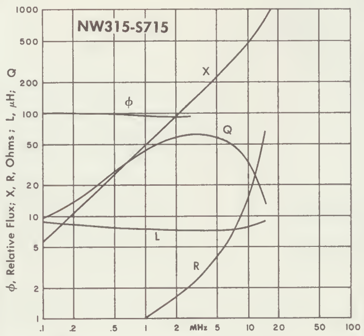
Single-Ended Writing Coil Data (See Note 1) Full Axis Values (Orange-White to Orange)

Type No.	Inductance at 1 kHz μH (See Note 2)	Current Amps I_d	Resistance Ohms Max.	Resonant Frequency MHz (Min.)
High Sensitivity, Precision Core, Low Residual Celcoloy				
AW314-S775	1-2.5	4.5	.03	25
-S750	2.5-4	2.5	.06	16
-S730	4-6	2.0	.12	12
-S715	6-8	1.2	.2	10
-S675	18	.8	.4	6
-S630	50	.5	1.	3
-S600	100	.4	2.	2
-S560	250	.23	5.	1.5
-S530	500	.16	8.	.8
-S500	1000	.12	20.	.5
Air Core No Residual				
BW314-S775	1-2.5	9.0 †	.03	18
-S750	2.5-4	5.0	.15	12
-S730	4-6	4.0	.2	10
-S715	6-8	2.4	.3	8
-S675	18	1.5	.7	5
-S630	50	1	2.2	2
-S600	150	.8	4.5	1.5
-S560	250	.5	12	1.0
-S530	500	.32	25	.5
-S500	1000	.24	50	.3
Hi-Q, Hi-Sensitivity for Highest Frequency Applications				
CW314-S775	1-2.5	4.5	.03	30
-S750	2.5-4	2.5	.06	22
-S730	4-6	2.0	.12	16
-S715	6-8	1.2	.2	14
-S675	18	.8	.4	8
-S630	50	.5	.5	4
-S600	100	.4	1	2.5
-S560	250	.23	5	2.0
-S530	500	.16	10	1.0
-S500	1000	.12	20	.6
Air Core with Ferrite Shield				
NW315-S775	1-2.5	7. †	.04	26
-S750	2.5-4	4.	.08	20
-S730	4-6	3	.15	14
-S715	6-8	1.8	.2	9
-S675	18	1.3	.7	7
-S630	50	.75	2	3
-S600	100	.5	5	2
-S560	250	.3	30	1.5
-S530	500	.22	70	.7
-S500	1000	.15	150	.4

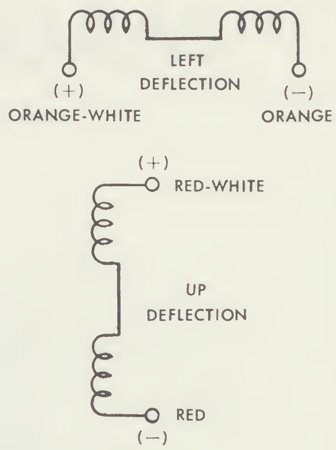




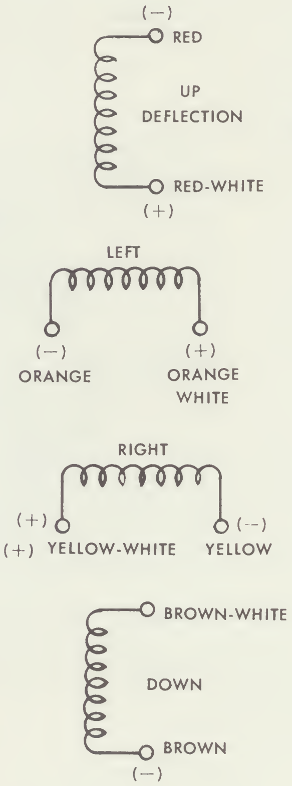




SINGLE-ENDED
4 Leads (Standard)



PUSH-PULL
8 Leads (Standard)



1. Push-Pull Yoke Available — Similar Parameters but Double Resistance
2. Horizontal Inductance Listed
   Vert. Inductance = 1.15 Horiz. Inductance

† Horizontal Current Listed
Vert. Current = 1.15 Horiz. Current

Special Inductances, Wiring Configurations, Terminations or Performances on Request

ORDERING INFORMATION